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SHIPBOARD EXPOSURE TESTING OF AIRCRAFT MATERIALS ABOARD USS RANGER

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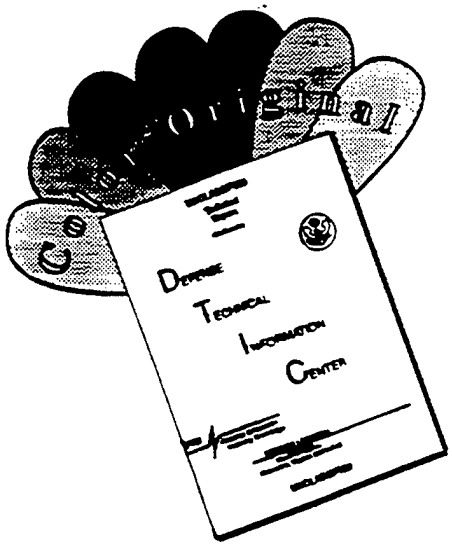

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13. ABSTRACT *(Maximum 200 words)*

This report describes the results of 4 months of exposure to the Naval Environment of an aircraft carrier flight deck on a variety of aircraft materials and coatings. Test specimens included aluminum-lithium alloys, metal matrix composites, laminates and primerless paint.

14. SUBJECT TERMS

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Shipboard Exposure Testing of Aircraft Materials Aboard USS Ranger (Jan-May 1991)

Introduction

A variety of aircraft materials and finishes are being exposed in the naval environment of aircraft carrier decks to provide information for the development of realistic and accelerated corrosion testing. In addition, the corrosion behavior of materials intended for application on present and future naval aircraft is being determined.

This report describes the effects of 4 months of exposure on a variety of aircraft materials and coatings aboard the USS Ranger during deployment to the Western Pacific and the Persian Gulf. The overall exposure aboard the Ranger was abbreviated, compared to the usual deployment. As a result, the aluminum control specimens and most of the other specimens sustained minimal corrosion. The magnesium alloys included in this exposure test experienced significant corrosion effects and are discussed in a separate report (Ref. 1).

Exposure Conditions

Exposure Rack

The rack face was made of expanded steel mesh which was cadmium plated, chromate conversion coated, and painted with MIL-P-23377 epoxy primer and MIL-C-81733 polyurethane topcoat. Specimens were insulated from the rack face by nylon washers and were fastened to the rack face with nylon bolts and nuts. MIL-A-46146 silicone rubber sealant was applied in the bolt holes of the specimens and under the bolt heads to prevent crevice corrosion. Specimens were exposed at a 45-degree angle to the vertical.

Weather Conditions

Weather reports were collected from hourly observations made by ship personnel on Form CNOC3140/8. From these reports, daily observations at 1200 hrs. and 2400 hrs. were recorded for atmospheric temperature, dew point, relative humidity, wind speed and sky cover. Table 1 shows the weekly averages for the atmospheric conditions. It is reported that temperatures at the carrier deck level can reach as high as 140°F(60°C), significantly greater than that of the ambient air. However, as seen in Table 1, ambient conditions were fairly uniform for most of the deployment. Atmospheric temperatures were greater that 68°F(20°C) most of the time and ranged typically from 72-85°F(22-29°C). The relative humidity varied typically from 62-84%. Conditions overall were not severe (as compared to the rainy season, for example) for a carrier environment.

Test Materials

Aluminum Alloy Control Specimens

One inch thick aluminum alloy 7075 T651 plate was machined into step specimens to expose the T/10 plane, with one tenth of the thickness removed, and the T/2 plane, with one half of the thickness removed. One step specimen was overaged to the T73 temper by heating for 24 hrs at 177°C (350°F), according to the Military Specification for Heat Treatment of Aluminum Alloys, MIL-H-6088F. The aluminum alloy exfoliation control specimens were prepared as follows:

1. Degrease
2. Etch in 5% NaOH at 80C (176°F), 3 min.
3. Rinse
4. Desmut in conc. HNO3, 30 sec.
5. Rinse in deionized water
6. Dry in oil free air

Additional aluminum control specimens consisted of 6061 T6 and 2024 T6 flat panels

Cadmium Plated Steel Control Specimens

Steel (Type 4130) panels were bright cadmium electroplated with average thickness of 0.3 mils, 0.5 mils and 1 mil and used as control specimens to indicate severity of exposure. Severe rusting of only the .3 mil cadmium plated panel indicates a relatively mild exposure.

Test Specimens

The test rack prior to exposure is shown in Fig. 1. Positions on the rack are numbered from top to bottom and left to right and described in Table II. Included as test specimens were aluminum-lithium alloys (and Russian versions), high temperature and high strength aluminum alloys in various forms, aluminum metal matrix composites and aramid aluminum laminates, coated magnesium alloys and aluminum alloys with Unicoat primerless paint coatings.

Results and Discussion

General

All shipboard exposed specimens were discolored and covered with a thin, gray film upon return. The analysis of similar films from previous exposures indicated the film consisted primarily of MIL-L-23699 engine oil deposits with some sulfur (Ref.2). Appearance of the test specimens after shipboard exposure is shown in Figures 2,3,4 for the left, center and right sections of the rack respectively. Observations of the individual specimens after exposure are summarized in Table II.

Control Specimens

Cadmium plated steel, Figure 2, shows severe rusting of the 0.3 mil Cd plated steel (lower specimen, third row from left), whereas the 0.5 mil Cd plate (center) shows some surface darkening and general rusting and the 1.0 mil Cd plat (top) shows surface darkening with only very slight general corrosion. These control specimens are indications of a relatively mild exposure.

Aluminum Alloy Control Specimens

A small but noticeable amount of exfoliation occurred on the T/2 plane of the 7075 T651 step specimen. By comparison, the 7075 T76 step specimen showed only a small amount of pitting and general corrosion, as expected from a relatively mild exposure, demonstrating the improved exfoliation resistance of the overaged T76 condition. The remaining aluminum alloy control specimens in flat sheet configuration showed only some pitting and general corrosion.

Aluminum-Lithium Alloys

The melt spun Al-Li-Zr alloy 644 (position 20) step specimen appeared to be starting to exfoliate on the T/2 plane. The Russian alloy 1420 (position 35) showed a small amount of incipient exfoliation on both faces. The remaining Al-Li alloy step specimens (position 14, 36) showed only general corrosion with no exfoliation. The Al-Li sheet specimens (positions 12, 44, 46) showed only general corrosion and some pitting, similar to the other test and 7075 T76 control specimens.

Other Materials

The high temperature aluminum alloys, high strength aluminum, aluminum metal matrix composites and aramid aluminum (Arall) laminates sustained somewhat similar general corrosion. No increase in corrosion was noted at the edges of the unsealed Arall laminate. The exposure was mild and nothing other than general corrosion was observed (position 33-34). The significant result was no edge attack of the ARALL laminate.

Paints and Coatings

The Unicoat (primerless) painted specimens (positions 27-32) showed basically no effects of corrosion but some blisters occurred at the scribe marks of the coated 2024 T3 specimens (positions 25, 26). The Unicoat protected the base material from corrosion. Some surface darkening was observed. The appearance of the chromate corrosion coating, the nonchromate corrosion coating, and Alodine under Unicoat was basically similar. There was some surface darkening, and blisters at scribe marks. The Alodine showed some evidence that blisters may be forming. The over all result is that a more severe environment or longer deployment time may be required to reveal significant differences in behavior.

Conclusions

1. The improved exfoliation resistance of 7075 T7 (overaged) aluminum alloy over fully aged 7075 T6 was demonstrated, even after a relatively mild exposure.

2. Corrosion behavior of the aluminum lithium alloys was comparable to that of the other aluminum alloys in this exposure.

3. Unicoat (primerless) paint provided sufficient protection of the alloy surfaces, with blisters forming only at scribe marks through the coating.

4. Differences in corrosion behavior among the other alloys in this exposure were not discernible.

References

1. Joseph Kozol and Edwin Tankins, "Aircraft Carrier Exposure Tests of Cast Magnesium Alloys," NAWCADWAR-93015-60, March 1993.

2. J. J. Thompson, "Shipboard Exposure Testing of Aircraft Material, Aboard USS Constellation (Feb.–Sept. 1985)," NADC-87125-60, Sept. 1987.

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Table I. Atmospheric Conditions - Weekly Averages.

Week	Atmos. Temp °C	Dew Pt. °C	Relative Humidity	Average Sky Cover	Average Wind Speed (Knots)
1	25	22.8	87	8	22
2	27.2	22.2	74	8	16
3	23.3	15.6	62	7	14
4	22.2	18.6	81	6.5	11
5	22.2	17.2	73	8	18
6	21	15	68.6	9	14
7	18.6	9.05	53.4	8.5	21
8	18.6	11.3	62.2	9	11
9	19.2	14.2	72.8	8	14
10	14.2	8.5	69	6	21
11	19.8	14.1	73	8	15
12	20.2	14.6	71.4	9	14
13	22.6	18	74.8	7	11
14	18.3	13.3	73	7.8	10
15	24	18.7	73	6.8	17
16	24.4	19.4	74	7.8	11
17	28.4	24.7	80	8.2	9
18	28.7	25.6	83.2	9	10
19	26.1	22.8	82	6.3	11
20	26.5	23.6	84	6	9
21	27.3	23.9	82	8	12
22	24.3	21.4	84	8	20

* On a scale of 1 to 10, 1 indicates clear skies and 9 indicates total cloud cover. 10 indicates thunderstorms.

TABLE II. SPECIMEN DESCRIPTION AND OBSERVATIONS

	Material Description	Designation	Configuration	Observation
1.	High Temp. Al alloy (Al-Fe-V-Si)	FVS 0812	Sheet	General corrosion, slight pitting not deep, slight surface discoloration.
2.	High Temp. Al alloy (Al-Fe-V-Si)	FVS 1212	Sheet	General corrosion, slight pitting not deep, slight surface discoloration.
3.	Aluminum Alloy	Control, 7075-T6	Sheet	Slight pitting not deep,and some general corrosion.
4.	Sealed Magnesium Alloy	WE-43		* Pitting of Al fitting, no galvanic corrosion discernible.
5.	Sealed Magnesium Alloy	QE-22		* No pitting, looks good.
6..	Unsealed Magnesium Alloy	QE-22		* Pitting of Al fitting with obvious galvanic corrosion at base of fastener.
7.	Cadmium Plated Steel (1 mil)	Control	Plate	Surface darkening, very slight general corrosion.
8.	Cadmium Plated Steel (0.5 mil)	Control	Plate	Surface darkening with edge corrosion.
9.	Cadmium Plated Steel (0.3 mil)	Control	Plate	Severe surface rusting.
10.	Aluminum Metal Matrix Composite	2124 T6, 15 vol SiC	Plate	Small amount of pitting, general corrosion and some surface discoloration.
11.	Aluminum Alloy	Control, 7075 T7351	Plate	Small amount of pitting, general corrosion and some surface discoloration.
12.	Al–Li Alloy (Russian)	1421	Welded sheet	Pitting and general corrosion.
13.	High Strength Aluminum Alloy	CW67T7	Plate	Small amount of pitting, some surface discoloration, mostly general corrosion.
14.	Aluminium-Lithium Alloy	2090T8	Step specimen	General discoloration, no exfoliation, general corrosion.
15.	High Strength Aluminum Alloy	CW67 T6	Plate	General discoloration, no exfoliation, general corrosion.
16.	Molybdate, Silane Coated Aluminum Alloy	2024 Coated	Plate	General discoloration, no exfoliation, general corrosion.

* Ref. 1.

TABLE II. SPECIMEN DESCRIPTION AND OBSERVATIONS (Continued)

	Material Description	Designation	Configuration	Observation
17.	High Strength Aluminum Alloy	CW67T7	Sheet	General discoloration, no exfoliation, general corrosion.
18.	Silane Coated Aluminium Alloy	2024 Coated	Plate	General corrosion, some pitting and surface discoloration.
19.	High Temperature Aluminum Alloy	CZ 42	Sheet	General corrosion, some pitting and surface discoloration.
20.	Melt spun Al-Li-Zr Alloy	644	Forged, extruded step specimen	General corrosion, some pitting and surface discoloration, exfoliation appears to be just starting at T/2.
21.	Aluminum Alloy	Control, 6061T6	Plate	General corrosion, and some pitting.
22.	Aluminum Alloy	Control, 2024T6	Plate	General corrosion, and some pitting.
23.	Aluminum Alloy	Control, 7075T76	Step specimen	Pitting and general corrosion.
24.	Aluminum Alloy	Control, 7075T6	Step specimen	Exfoliation starting on mid plane. No evidence on top plane.
25.	Chromate Corrosion Coating, Unicoat Variation	2024T3	Plate	Blisters at scribe marks. Paint Surface looks good.
26.	Chromate Corrosion Coating, Unicoat Variation	2024T3	Plate	Blisters at scribe marks. Paint Surface looks good.
27.	Non-Chromate Corrosion Coating, Unicoat Paint	2024T3	Plate	No corrosion, some surface darkening.
28.	Non-Chromate Corrosion Coating, Unicoat Paint	7075T6	Plate	No corrosion, some surface darkening.
29.	Non-Chromate Corrosion Coating, Unicoat Paint	6061T6	Plate	No corrosion, some surface darkening, blisters may be forming.
30.	Alodine, Unicoat Paint	2024T3	Plate	Blisters may be forming.

TABLE II. SPECIMEN DESCRIPTION AND OBSERVATIONS (Continued)

	Material Description	Designation	Configuration	Observation
31.	Alodine, Unicoat Paint	7075T76	Plate	No corrosion, some surface darkening.
32.	Alodine, Unicoat Paint	6061T6	Plate	No corrosion, some surface darkening.
33.	Aramid Aluminum Laminate	Arall 5/4	Unsealed edges	General Corrosion - No discernible increase at laminated edges.
34.	Aramid Aluminum Laminate	Arall 5/4	Sealed edges	General Corrosion.
35.	Al-Li Alloy (Russian)	1420	Step specimen	Incipient exfoliation on both faces.
36.	Al-Li Mechanically Alloyed	Inco 905XL	Forging Step Specimen	No exfoliation, some pitting and general corrosion.
37.	High Strength Aluminum Alloy	CW67T7X1	Forging	Some pitting and general corrosion.
38.	Aluminum Metal Matrix Composite	2124 T6, 15 vol SiC	Sheet	Some pitting and general corrosion.
39.	High Temp. Aluminum Alloy	Al-12.6Mn, 4.8Si, 0.2 Fe	Extrusion	General corrosion, similar to #1 except darker discoloration.
40.	High Temp. Al Alloy (Al-Fe-V-Si)	FVS 1212	Extrusion	General corrosion, some pitting and surface discoloration.
41.	Unsealed Magnesium Alloy	QE-22		* Pitting of Al fitting, galvanic corrosion; coating at scribe in base material severely corroded.
42.	Sealed Magnesium Alloy	QE-22		* Severe corrosion at scribe, not as bad as #41.
43.	Sealed Magnesium Alloy	WE-43		* Tiny amount of corrosion at scribe, no galvanic effects noted.
44.	Al-Li-Mg Alloy (Russian)	1420w	Sheet	General corrosion, some surface discoloration.
45.	High Temp Al Alloy (Al-Fe-V-Si)	FVS 0812	Sheet	Incipient pits, slightly more general corrosion than #1.
46.	Al-Li-Mg Alloy (Russian)	1421w	Sheet	Some pits, general corrosion.

* Ref. 1.

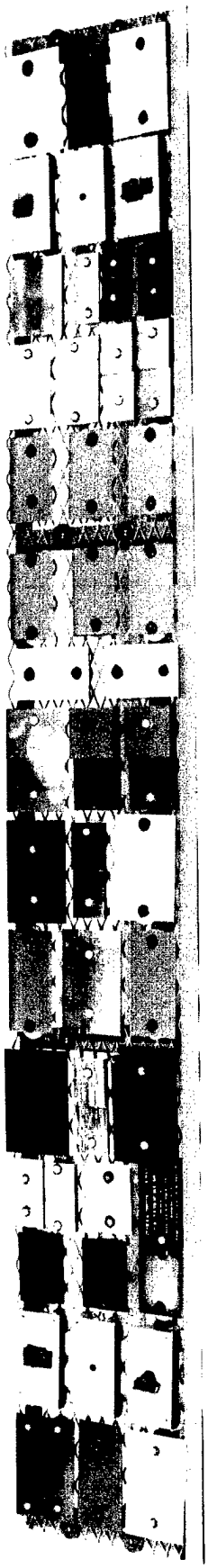

Figure 1. Test Specimens Prior To Shipboard Exposure.

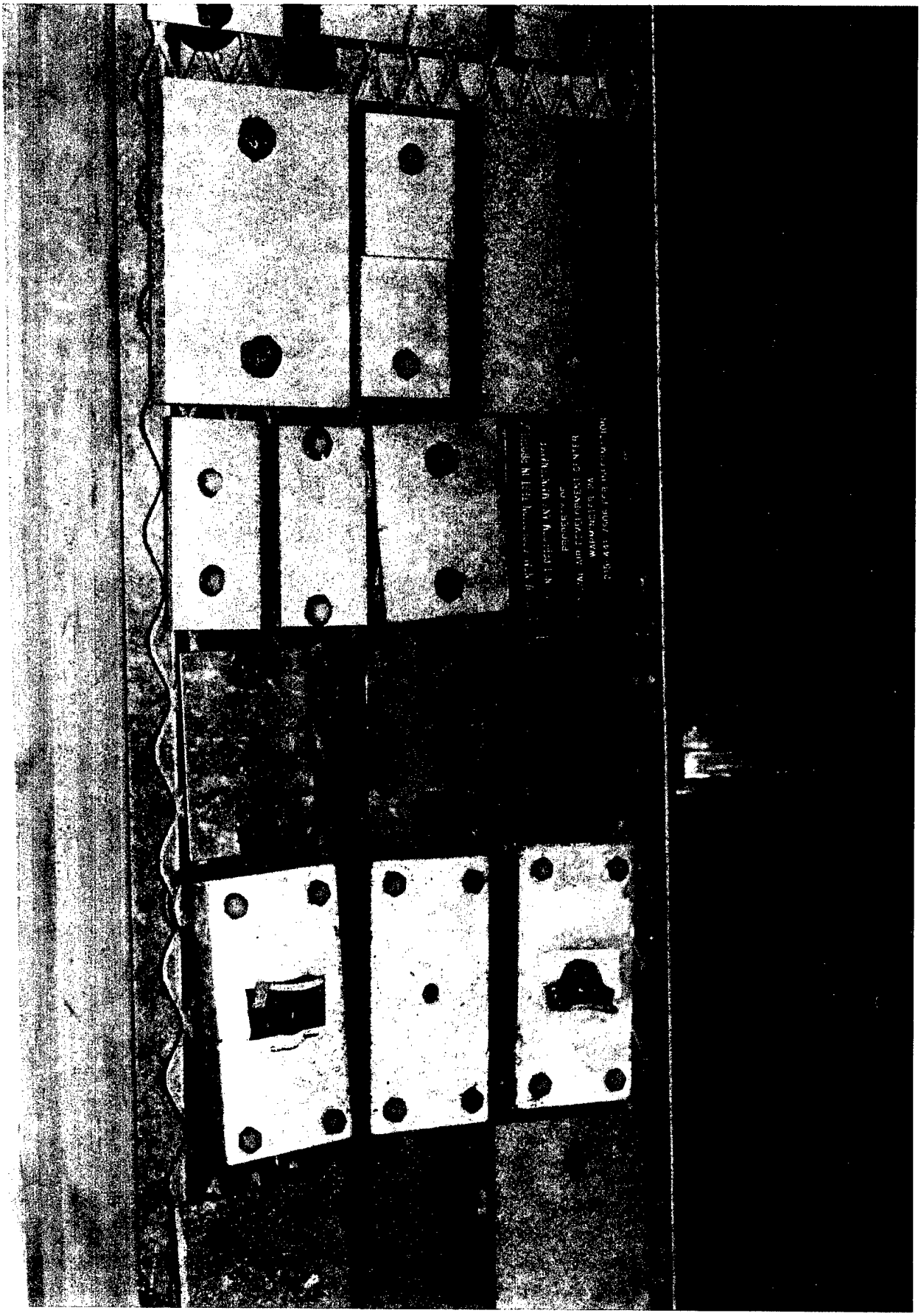

Figure 2. Left Section Of Rack After Exposure.

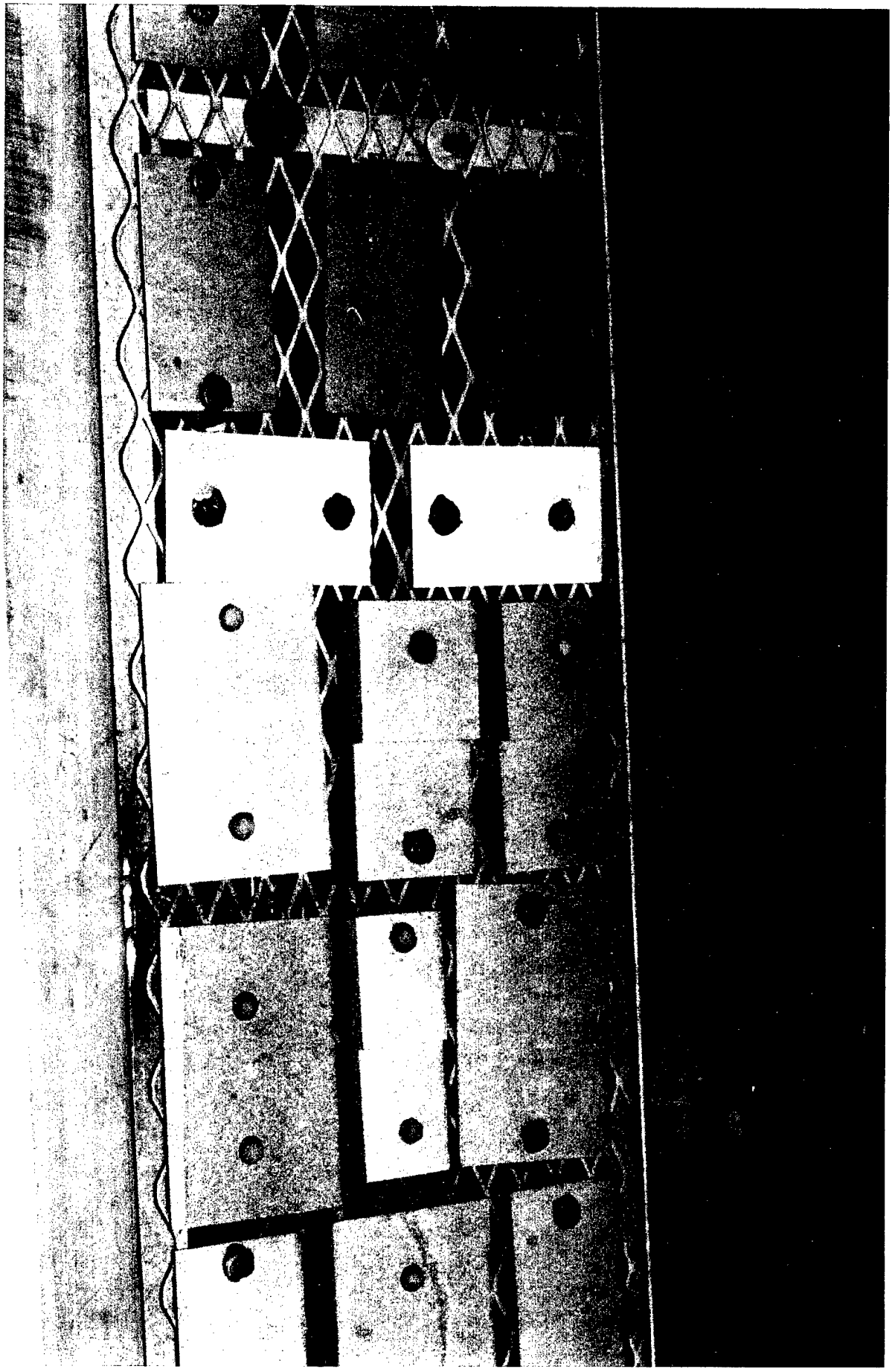

Figure 3. Center Section Of Rack After Exposure.

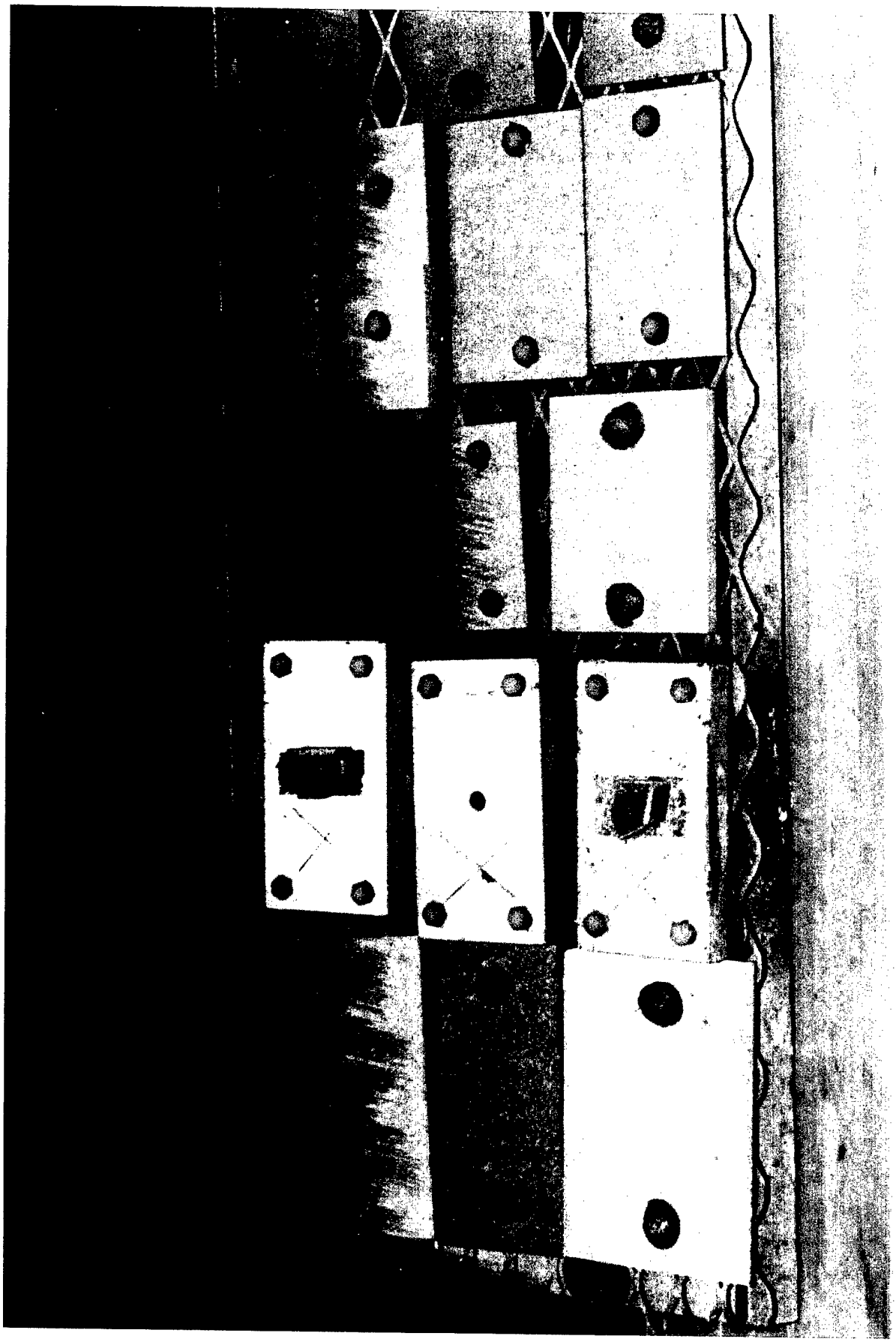

Figure 4. Right Section Of Rack After Exposure.

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